

603921

COPY

AD 603 ~~HE~~ 921
P-215
May 51

1 cy
25 Aug 64

EFFICIENCY ASPECTS OF DISPERSAL OF POPULATION AND IN-
DUSTRY - T.C. Koopmans

Action:

Mf:

15p

hc \$1.00

Jrnl. iss.:

eb

Pub:

mf \$0.50

Rel. date:

003901

EFFICIENCY ASPECTS OF DISPERSAL OF POPULATION
AND INDUSTRY

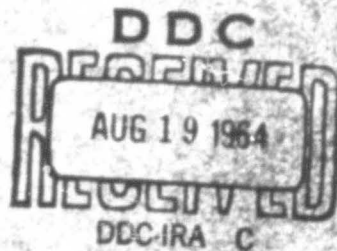
Tjalling C. Koopmans

P-215

May 1951

Approved for OTS release

15 p \$1.00 hc
\$0.50 mf



The RAND Corporation

SANTA MONICA • CALIFORNIA

EFFICIENCY ASPECTS OF DISPERSAL OF POPULATION
AND INDUSTRY

Tjalling C. Koopmans,*

Cowles Commission for Research in Economics

The University of Chicago

1. Introduction

I should like to start by explaining that I am inadequately prepared for a discussion of the topic of dispersal. I think what happened is that over the last year or so I expressed an opinion to whoever was willing to listen to me that dispersal is an important and urgent problem, and as a result of these repeated promptings I have been assigned the task of introducing that problem. I have no knowledge of the technology of bombing, and of other factors relevant to the allocation of resources as between offense and defense. Hence I can deal only with those efficiency aspects of the dispersal problem that I feel I can say something useful about.

The purpose of dispersal, I take it, is to diminish the damage that can be inflicted by an enemy through a given application of resources to his attack. For any given geographical distribution of population and industry, that damage consists of two parts. One is the actual destruction caused by enemy attack, including the loss of production that results from the falling out of productive capacities and population. The other is the amount of defensive facilities and resources that we put into action or hold in readiness in order to diminish the first component of damage. I am assuming that we have already optimally allocated available military

* Work under contract between the Cowles Commission and the RAND Corporation. I am indebted to A. P. Lerner and to J. Marschak for valuable comments on the subject-matter and presentation of this paper.

strength as between offense and defense, and as between the defense of the various conglomerations of industry and population which are exposed. I am therefore counting as total damage inflicted the sum of actual damage and the withdrawal-from-other-uses of resources allocated to defense, at the optimum level decided by ourselves. The diminution of this damage to be expected from a given dispersal plan must be balanced against the transition cost of dispersal (including production foregone while moving) and the decrease or increase in productive efficiency resulting from that dispersal.

There is, of course, the question in how far an enemy is informed about the actual locational distribution, and about the relative importance of the various productive facilities for our ability to wage war. To the extent that there is misinformation on either of those two counts, we need not disperse as much as we otherwise would need. We can put more eggs in one basket if the enemy doesn't know where the basket is. But I shall assume that we cannot count on such misinformation, if only because I have no idea what we would have to assume otherwise. I shall therefore assume that the type of information involved cannot be withheld from an enemy and hence that we have to seek as much protection in dispersal as is justified by balancing the benefits from such protection against the costs.

2. On the Measurement of Exposure.

In attempting to diminish the damage that can be inflicted by an enemy through a given application of resources, it is clear that the place where these offensive resources are applied is the choice of that enemy. We must therefore determine that damage as a function of the location at which the enemy aims, given the geographical layout of productive facilities and activities as it is, and given the allocation of defensive resources to

various areas or locations we have made. We need to find a unit or measure in which to express, as a function of location, the exposure that would result from a unit of enemy offensive resources being applied to a given location or area. Various measures have been used; one is population, another is value added according to the census of a given year. The correlations between these and other measures have been determined for a large collection of localities, and the correlations were, on the whole, high. Any of these measures may therefore be a good first approximation, but there are still doubts as to how good. For instance, the money value added in peace time may have little relationship to the degree of essentiality that attaches to a certain productive facility in a war economy.

It would seem that a second approximation can be obtained with the use of what has come to be called activity analysis, provided this activity analysis be extended to cover dynamic situations. I should like to elaborate briefly on this, explaining at the same time that I am mainly concerned with concepts. When it comes to collecting data and making computations, compromises will have to be made; but we can intelligently make these compromises only if we have first obtained clarity about the concepts. I am confining myself to that aspect of the problem.

The basic postulates of the linear form of activity analysis that has been developed involve two classes of elements: commodities and activities. An activity can be any industrial process or any other action whereby certain commodities are used up and certain other commodities are produced, and each activity is characterized by the ratios in which the various commodities are used up and produced. It is further assumed that each activity can be given any non-negative level, and that the various outputs and inputs are proportional to the chosen level of the activity. There is thus a matrix

of input-output coefficients, each column representing an activity, each row referring to a commodity. This matrix represents the technology of the country. There is further a vector of activity levels. Finally, we can consider that some of the commodities are available as basic resources coming to us from nature, such as water power, minerals, arable land, labor, and so on. Limits are placed by nature and population on the maximum amounts available of these primary resources.

The problem of efficiency now is to determine what combinations of activities (vectors of activity levels) are efficient, as distinct from other combinations that involve an element of waste. Whenever you have a combination of activities such that the output of one commodity cannot be increased, within the limits on primary resources, except by changes in activity levels that simultaneously decrease the output of another commodity, then we say that efficiency has been achieved. In general there will be infinitely many efficient combinations of activities, but there will be "still more" inefficient combinations.

The main result of this analysis* that I want to use is that, whenever such an efficient combination of activities exists, we find associated with it a set of prices or valuations on the commodities involved, with the following meaning: If instead of this particular efficient combination of activities you want a neighboring one which produces more of just one given commodity and less of just one other commodity, then a comparison of the two "efficiency prices" in question tells you in which ratio you are exchanging one commodity against another. This is a technological valuation; it is

* See Activity Analysis of Production and Allocation, Cowles Commission Monograph 13, in particular Chapter III, "Analysis of Production as an Efficient Combination of Activities," by T. C. Koopmans.

independent of a market, and this is important with respect to the war-time situation I am speaking of. In a war-time situation we are likely to have price control. The money prices of goods and services are then determined mostly with a view to their effect on the income distribution, and thereby on morale and unity of purpose. As a result the money prices of commodities have no longer a definite relation to the intrinsic value of each commodity to the war effort, or, putting it another way, to the damage that would be sustained by the removal of one unit of that commodity from the economy. The efficiency prices just referred to provide such an intrinsic valuation. On the other hand, in the absence of price control of monopolistic policies of firms or government, competitive markets will give rise to money prices that are equal to the efficiency prices, and profit seeking decisions in response to these prices will lead to efficient use of resources.*

I believe that this notion of efficiency prices can be duly extended to capital facilities, and to production programs that change over time. (In this case the capital equipment of the country at the beginning of the planning period must be included with the primary resources referred to above.) Under the assumption that this extension of the concept of efficiency prices is possible, the numerical evaluation of all the efficiency prices of the various amounts and types of capital equipment that are exposed to this risk would allow us to compute a local exposure function. This is a function of locational coordinates that tells us how much damage could be done to our war economy by the application of one unit of offensive resources to that location by an enemy. We can now give also a little better meaning to this

* To be precise, this statement has been rigorously proved only for a state of static equilibrium. To explore its extension to dynamic situations, one would have to specify, inter alia, the extent to which individuals or firms receive information about each other's plans, through markets for future delivery or otherwise.

notion of one unit of offensive resources by an enemy. If the enemy has to make a longer trip to reach one location rather than another, then the composition of the bundle of resources he will employ may be different, possibly more gasoline, relatively fewer airplanes used, but more airplanes lost, and so on. We now assume that, by a similar analysis of the enemy economy, commensurability is also established between the enemy's several resources.

One other thing I must explain is that the local exposure function so defined will in general be applicable only for relatively small amounts of destruction. By relatively small I mean small in relation to the total productive capacity of that industry in the country. The interpretation of the efficiency prices that I have mentioned applies to small variations in the combinations of activities, but need not apply to large variations.

We must also take account of the efficiency value of population, of casualties. We are on very uncertain ground here. It is possible, of course, to measure the potential labor contribution that is lost when a casualty occurs, and that is the easier part of the allowance to be made. In addition to that, there is the value of human life for its own sake, and the effect on morale if casualties are running high, both of which I would not know how to express. Nevertheless, somebody should face up to placing a calculated value on the preservation of life and limb. Human exposure is definitely a factor of varying importance in different locations, and we cannot help making decisions implying such valuations. So we should make these valuations explicit.

3. On Locational Redistribution

I assume then that we have a function of location which tells us what degree of exposure is found in any given location. Let us remember that in

the reasoning that led us to construct this function, resources allocated to defense were already assumed to be optimally distributed over various locations. It is conceivable that as a result of this the local exposure function has little variation left in it, even though high concentrations of production and population remain. This would be the case if so much defense can be provided for these concentrations as to make them into bastions no more attractive to enemy attack than other areas with much lower concentration of industry and population.

Without being in a position to prejudge the issue, I shall assume for the sake of argument that not enough resources are available for defense, under a best allocation of military strength as between offense and defense, to obtain a fairly constant local exposure function without dispersal. It will then be worthwhile to devote resources to a dispersal which reduces the high peaks of local exposure most attractive to enemy attack, while filling up some of the valleys to levels of exposure at which attack remains relatively unrewarding. This can be done in the first place at small cost by careful choice of location of new plants. With respect to existing plants there is an active and a passive approach. The passive approach is to wait for destruction when it occurs and then to reconstruct the facilities in some other location which is less exposed. The active approach is to move existing plants or activities to less exposed locations.

At this point I must reiterate that I do not have the knowledge to assess to what extent this active version of the second method is worth doing, though I believe it is. In what follows I am therefore assuming it to be found that the result of such active relocation is worth the cost. I shall devote the remaining remarks to the question of how to do it most efficiently.

Before taking that up, let me say a few words about the question of the

most efficient locational distribution of industry in peace time, a problem always with us. If we were to look at that as a problem to be solved by an explicit computation, the data going into it would be such things as the availability of land and other natural resources, the initial capital equipment and its distribution by locations, data on climate and human preferences as between climates, and information about the technological possibilities of production, also as affected by climate, and, in particular, the technology of transportation.

However, before we look at this as a computation problem, let us ask ourselves whether, in this area, the faith of economic liberalism is applicable. This faith is that individual profit- or welfare-seeking decisions, taken under conditions of perfect competition by many private entrepreneurs and individuals, bring about efficient allocation of resources. (We have already stated that, whenever the linear model of activity analysis described above is applicable, that faith has been buttressed by formal mathematical proof.) I believe, however, that there are certain reasons, associated particularly with the decisions that bring about the locational distribution of industry, for doubting that the normal peace time pursuit of profit does effectively bring about an optimal geographical distribution of industry. One of those reasons for doubt is that the economist's ideal of competition has failed to penetrate to important categories of decisions. For instance, railway rates do not at present reflect efficiency prices of transportation services. The point is quite simple, and can be illustrated by an example of a railroad connecting two terminals, A and B. If a certain amount of goods has to be moved daily from A to B and a smaller amount from B to A, then loaded cars will go from A to B, and both loaded and empty cars will go from B to A. Now if you add a trainload to the daily goods traffic from A to B, this

commits you to run that additional train back empty from B to A. Therefore the actual cost, in terms of utilization of equipment of that addition to transportation services rendered, is represented by the time the train has to take for that whole round trip. On the other hand, if you add one train-load to the daily movement of goods from B to A, the only extra train-time you are committing is the time necessary to put the goods on the train at B and again to take them off at A. For otherwise that train would have been returned empty anyway. So to get a best locational distribution of industry from individual decisions, it would be necessary that freight rates are set that recognize this fact and express actual cost incurred by the railway system for each addition to transportation services rendered. Such "directional" efficiency freight rates are not in use.* There are mistaken ideas of fairness predominant in the official approval of freight rates, and these have prevented industry from finding its best locational distribution. In particular the effect has been that some industry has remained in the East that would otherwise have moved further to the West or South.

In any case, adjustments to the locational distribution arising from individual decisions are very slow. The moving of an enterprise is a decision that may be considered once in 30 years, or less frequently. Moreover, the motivations are partly irrational, depending on the ties that the deciding individuals have in an area. Finally, the problems in question are really non-linear--the question of optimal size of cities is very closely connected with the question of indivisibilities. A larger city may be a

*See "Optimum Utilization of the Transportation System," Econometrica, Vol. 17, Supplement, July 1949 (Report of the Washington Meeting of the Econometric Society held in conjunction with the International Statistical Conferences, September 6-18, 1947), pp. 136-146, by T. C. Koopmans.

See also "A Model of Transportation," by T. C. Koopmans and S. Reiter, in Activity Analysis of Production and Allocation, Cowles Commission Monograph 13.

more efficient producing unit because it allows greater specialization of functions between firms and between individuals. A smaller city may not be able to support even one of these specialized types of firms, or its firms cannot reap the full advantages of internal specialization and mechanization that go with large-scale production.

Thus there is a tendency toward increasing returns to scale which favors the large city. An opposing tendency arises from another non-linear relationship. Consider certain activities spread out in a city, and consider next another city which is twice the size (by area as well as by output), but is a scale model of the earlier one in regard to the location and amount of activities. Then the amount of transportation involved between the producing sectors of the city has been multiplied by more than a factor 2 because quantities twice as large are to be handled over distances enlarged roughly in the ratio $\sqrt{2}$ to 1. The presence of two non-linear relationships makes it possible for there to be a relative optimum in the allocation of resources, considering only small changes in the distribution of industry, which is not an absolute optimum in comparison with more radically changed distributions. We can no longer rely on what in linear activity analysis has been an important property of the model of technology--that a relative optimum in the allocation of resources is necessarily an absolute optimum. Even if the obstacles to the formation of competitive or efficiency prices were removed, the economy might hover near the top of a hill in the landscape of efficiency, without the possibility of a jump to the top of a higher mountain being noticed.

The question should be considered whether we have enough valid analysis to compute at least a better distribution of industry, even for peace time purposes, than the existing one. I believe that in some respects we can prepare improvements in the realism of such computations, in others we cannot

yet. The effect of the freight rates not reflecting efficiency prices I think is a matter which is open to correction by computation. That is, we can construct better distributions of industry if we take into account efficiency freight rates. About the effects of the non-linear relationships described I am less confident. I think we are very much at the beginning of increasing our understanding of these complications and I do not know if at some time we shall feel confident that we can cover this aspect computationally.

However, let us now assume that, by computation and by dealing with aspects that computation can grasp, we shall be able to improve on the existing distribution. Then we shall also be able to guide a relocation that is designed to bring about a decrease in the peaks of the local exposure function.

Let us now come back to the problem of finding the best relocation plan meeting that objective. It might be thought that, more precisely, the objective of such a relocation plan should be to depress all high peaks of the local exposure function to some common maximum allowable level. This might indeed be a correct formulation of the objective if the transition cost of removing one "unit of exposure" were the same in all peaks of the exposure function. However, there is no reason why this should be so. Some industries could no doubt be moved more cheaply than others. Therefore it may be justified to depress certain peaks more than others because it takes less resources to do so. One guiding objective would then be to maximize the reduction in allover exposure that can be obtained from a given allocation of resources to meet the transition cost of dispersal. Another objective would be to choose such new locations as will maximize the productive efficiency of the resulting geographical distribution of industry. Where these objectives conflict, the weight to be given to each will depend on an estimate of the importance of making savings on transition cost at the expense of

ultimate productive efficiency (that is, an estimate of the "real" rate of interest that expresses the social preference for present over future goods, a preference which is likely to be high in a war situation).

By what means or methods can these objectives be pursued? A pamphlet of the National Securities Resources Board called "National Security Factors in Industrial Location" has started to approach the question of how to bring about relocation by influencing the decisions of individual firms. They have given the entrepreneurs some criteria, such as this: Draw a circle of three miles or five miles around your plant. If within that circle there is a good deal of industry that appears valuable to a war effort, then that is not a good location and you should move to some other location. The best that can be said about this advice is that it is just a little better than nothing. At the same time it is woefully inadequate. The method of influencing individual decisions by such indirect persuasion is too slow if a substantial relocation is indicated. If we need a fast change (and by fast I mean, say, a relocation taking ten to fifteen years), we cannot leave it to individual decisions, because a firm that should want to make a good decision doesn't have the information that would enable it to do so. It does not know what the distribution resulting from relocation is going to be and therefore cannot find its own best place in that resulting distribution. It follows that some systematic computation effort is indispensable if we decide that we have to bring about a relocation in a relatively short period.

A method at the opposite extreme would be to compute some master plan and just issue instructions to at least a substantial number of key firms as to where to move their establishments. I see great difficulties in this method of centralized decision making. The computation, however extensive, is bound to be very imperfect. There will be many firms that will feel

that hardships are placed upon them because the agency arranging the computation has not effectively considered things that are very important to the life of that firm or enterprise. So I wonder if a method of successive approximations is feasible. First one computes a master plan and derives from that a tentative relocation identifying new locations for the most important firms, the firms that produce more than a given amount, say. Then one informs these firms about the resulting distribution according to the master plan, about their own place in it, and about the distribution of their own industry, and of their supplying and consuming industries. Then one seeks some kind of approval or amendment from the individual firms. On the basis of the response so received, a recomputation of the master plan is made, and so on. The way would be smoothed further by setting up certain tax incentives for the firms to move. The wheels would have to be oiled by subsidies if and where necessary. And the administration of such a plan would have to cut across local authority.

4. Conclusion.

There is no doubt that dispersal is a problem of great complexity. If the assumptions of this discussion are correct, it is at the same time a problem of great urgency. While it has been discussed here primarily in terms of efficiency of a preparedness or war effort, an even deeper issue is involved. Failure to increase our protection in dispersal may create a conflict between the high value we place on the preservation of human life as an end in itself and other values, such as individual freedom and the democratic decision process, which we stand ready to defend by war if necessary. The present precarious position of Western European countries illustrates the impairment of freedom of action that may arise from a rate of local exposure much higher than that applying at present to the American

continent. Freedom of action should be preserved in the most important center of decision in the democratic world. In addition, dispersal reduces the probability of war, because it gives less ground to the assumption on the part of an enemy that a war can be won quickly. The question of dispersal should therefore be taken up in all seriousness.

There is a definite risk that we shall always find very good and urgent reasons for not yet embarking on such a relocation, such as that the facilities in question are needed immediately and without interruption. This reasoning is cumulative in its effect and nothing may be undertaken which is sufficient over time to maintain our freedom of action. As the development of weapons and methods of attack goes further, we may in the end then find ourselves in a degree of exposure where we would not have wanted to be had we considered this question systematically from the beginning.

mc